We claim:

1. A method for characterizing and repairing defects using image reconstruction from diffraction patterns, comprising:

providing a sample for testing for the location of a defect within said sample;

illuminating, with a beam, a series of areas of said sample, to create a series of two-dimensional diffraction patterns;

producing a three-dimensional diffraction pattern from said series of two-dimensional diffraction patterns;

computationally producing a reconstructed image of said sample from said three-dimensional diffraction pattern;

determining the location of said defect within said sample from said reconstructed image; and

repairing said defect by applying an appropriate repair technique depending upon the location of said defect within said sample.

2. The method of claim 1, wherein said beam comprises an X-ray beam.

3. The method of claim 1, wherein said beam comprises extreme ultraviolet light.

4. The method of claim 3, wherein said extreme ultraviolet light comprises a wavelength of 13.7 nm.

5. The method of claim 3, wherein said beam comprises a harmonic of said extreme ultraviolet light.

6. The method of claim 5, wherein said beam comprises a harmonic of 13.7 nm.

7. The method of claim 1, wherein said beam comprises an electron beam.

8. The method of claim 1, wherein said beam is elastically scattered by said sample.

9. The method of claim 1, wherein said series of areas are selected by rotating said sample.

10. The method of claim 9, wherein said sample is rotated around Ψ and Θ, and at each position a two-dimensional diffraction pattern is recorded, wherein these diffraction patterns are parts of an Ewald sphere in reciprocal space, and wherein rotating said sample will lead to exploring the full reciprocal space by rotating said Ewald sphere.

11. The method of claim 1, further comprising capturing said series of two-dimensional diffraction patterns prior to producing a three-dimensional diffraction pattern.

12. The method of claim 11, wherein the step of capturing said series of two-dimensional diffraction patterns is carried out with a CCD camera.

13. The method of claim 1, wherein said sample comprises an EUVL multilayer film.

14. The method of claim 1, wherein said beam is focused.

15. The method of claim 1, wherein the step of computationally producing a reconstructed image includes applying a technique for image reconstruction from diffraction patterns on said three-dimensional diffraction pattern.

16. The method of claim 15, wherein said technique for image reconstruction from diffraction patterns comprises an iterative algorithm.

17. The method of claim 15, wherein said technique for image reconstruction from diffraction patterns comprises a phase retrieval algorithm.

18. The method of claim 1, wherein said sample comprises a multilayer of Mo/Si.

19. The method of claim 1, wherein said sample a magnetic thin film.

20. The method of claim 1, wherein said sample comprises a Cu film.

21. The method of claim 1, wherein said sample comprises a reticle with a thin film coating, wherein said reticle is for use in an extreme ultraviolet

lithography (EUVL) system, wherein the step of repairing said defect comprises changing the thickness of said thin film coating in the vicinity of said defect.

22. The method of claim 21, wherein said thin film coating comprises a multilayer coating having multiple layer boundaries, wherein the step of changing the thickness of said thin film coating in the vicinity of said defect includes interdiffusing at least one layer boundary of said layer boundaries.

23. The method of claim 21, wherein said thin film coating comprises a multilayer coating having multiple layer boundaries, wherein the step of changing the thickness of said coating in the vicinity of said defect includes altering the density of at least one layer of said multilayer coating.

24. The method of claim 21, wherein said thin film coating comprises a multilayer coating having multiple layer boundaries, wherein the step of changing the thickness of said thin film coating in the vicinity of said defect includes interdiffusing a plurality of said layer boundaries.

25. The method of claim 22, wherein the step of interdiffusing at least one layer boundary includes controlling the multilayer contraction associated

with the densification that occurs upon interdiffusion at said at least one layer boundary.

26. The method of claim 25, wherein the step of controlling the multilayer contraction includes activating the step of interdiffusing using a localized energy source.

27. The method of claim 26, wherein said localized energy source comprises an electron beam.

28. The method of claim 27, wherein said electron beam is focused.

29. The method of claim 26, wherein said localized energy source is selected from the group consisting of an electromagnetic beam, an electron beam and an ion beam.

30. The method of claim 29, wherein said localized energy source is focused.

31. The method of claim 26, wherein said localized energy source comprises an electrode.

32. The method of claim 21, wherein said defect comprises a mound or protrusion caused by multilayer deposition over a particle, wherein said defect is mitigated by decreasing the multilayer film thickness at the position of said defect, or spreading the sides of said mound, thereby reducing the slopes of said defect.

33. The method of claim 21, wherein said defect comprises a depression caused by multilayer deposition over a pit or scratch, wherein said defect is mitigated by increasing the multilayer film thickness at the position of the said defect, or spreading the sides of said depression, thereby reducing the slopes of said defect.

34. The method of claim 21, wherein said thin film coating comprises a reflective multilayer structure.

35. The method of claim 21, wherein said multilayer coating is used as a buffer layer, wherein said EUVL reticle further comprises a reflective multilayer coating deposited on said multilayer coating.

36. The method of claim 21, wherein said multilayer coating comprises

Mo/Si.

37. The method of claim 25, wherein said densification comprises silicide formation.

38. The method of claim 29, further comprising controlling the decrease in thickness of said multilayer coating by adjusting the energy dose of said localized energy source.

39. The method of claim 29, further comprising adjusting the energy dose of said localized energy source to control the decrease in film thickness with sub-nanometer accuracy.

40. The method of claim 29, further comprising controlling the lateral spatial resolution of the localization of energy deposition produced by said localized energy source.

41. The method of claim 29, wherein the depth of the deformation is controlled by adjusting the exposure time of said localized energy source.

42. The method of claim 1, wherein said sample comprises a multilayer coating wherein said defect comprises an amplitude defect in said multilayer coating, wherein said defect is selected from the group consisting of a particle, a shallow pit and a scratch, wherein the step for repairing said defect comprises removing said defect that is causing said amplitude defect from said multilayer coating, wherein a damaged region of said multilayer coating will remain after removal of said defect, wherein said step for repairing said defect further comprises etching away said damaged region.

43. The method of claim 42, wherein the step of etching away said damaged region is carried out without disturbing the intact underlying layers of said multilayer coating.

44. The method of claim 42, wherein the step of removing a particle includes milling said particle out of said multilayer coating.

45. The method of claim 44, wherein the step of milling is carried out with a focused ion beam (FIB).

46. The method of claim 45, wherein said FIB is operated near normal incidence.

47. The method of claim 45, wherein said FIB has a diameter less than 100 nm.

48. The method of claim 45, wherein said FIB comprises a gas source.

49. The method of claim 48, wherein said gas source comprises a gas selected from the group consisting of He, Ne, Ar, Xe, F, Cl, I and Br.

50. The method of claim 45, wherein said FIB comprises a liquid metal source.

51. The method of claim 50, wherein said liquid metal source comprises a liquid metal selected from the group consisting of Ga, Si, In, Pb and Hg.

52. The method of claim 45, further comprising imaging said defect with said FIB.

53. The method of claim 42, further comprising imaging said defect during the step of removing and the step of etching.

54. The method of claim 53, wherein the step of imaging is carried out using a focused ion beam.

55. The method of claim 42, wherein the step of etching away said damaged region is carried out using an ion beam having a voltage of less than 5000 V.

56. The method of claim 55, wherein said ion beam has a diameter within the range from about 10 nm to about 1 mm.

57. The method of claim 55, wherein said ion beam is rotated with respect to said multilayer coating to improve the uniformity of the etching process.

58. The method of claim 42, wherein the step of etching away said damaged region is carried out at a temperature less than 200 °C.

59. The method of claim 42, wherein the step of etching away said damaged region produces a crater in the surface of said multilayer coating that has a diameter of greater than 10 μm and a depth of less than 150 nm.

60. The method of claim 42, wherein the step of etching away said damaged region is carried out using an ion beam at an angle of incidence that is less than 20 degrees from the surface of said multilayer coating.

61. The method of claim 60, wherein said ion beam is rotated with respect to said multilayer coating to improve the uniformity of the etching process.

62. The method of claim 44, further comprising removing atoms implanted by milling step to remove defect

63. The method of claim 42, wherein said particle is on the top of, or imbedded near the surface of, said multilayer coating, surrounded by a localized region of damaged multilayer coating.

64. The method of claim 42, further comprising minimizing the slope of the surface of said multilayer coating in the repaired region.

65. The method of claim 42, further comprising depositing a Si layer subsequent to the step of removing a defect, wherein said Si layer is about 1 to 4

nm thick, wherein said Si layer limits oxidation of the exposed multilayer coating.

66. The method of claim 1, wherein said defect comprises an amplitude defect in a multilayer coating, wherein the step of repairing said defect comprises physically removing said defect from said multilayer coating and leaving a wide, shallow crater that exposes the underlying intact layers to restore the local reflectivity of the coating.

67. The method of claim 42, wherein the step of repairing said defect is carried out with an Atomic Force Microscope (AFM) having the capability to produce a crater.